Magnetohydrodynamics: H2OTSTUF

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Two activities are underway in the area of magnetohydrodynamics (MHD). The first, called H2OTSTUF, is an investigation of using high temperature water as the medium for an MHD generator and accelerator. The second called "Investigations of External MHD Slipstream Accelerator Technologies," investigates the use of external electromagnetic fields to accelerate the air flowing past the vehicle for propulsion.

Several studies have examined the use of MHD accelerators and generators to augment current chemical, nuclear, and solar thermal rockets. These studies have relied heavily on analytical models and numerical codes to calculate performance. Little experimental data is available to verify these predictions. Among the experimental works that have been performed are those of NASA Langley Research Center and Arnold Engineering Development Center. The work at these centers on MHD accelerators for accelerating air in a hypersonic wind tunnel was performed about 35 years ago.[1,2] During this same time Dr. Vadim T. Alfyorov started a program to develop an MHD augmented hypersonic test facility at the TSAGi research center. This work continues today, and a small-scale facility is operational. It produces very high velocity flows, but at temperatures too high to simulate the correct Mach numbers for hypersonic flow.[3]

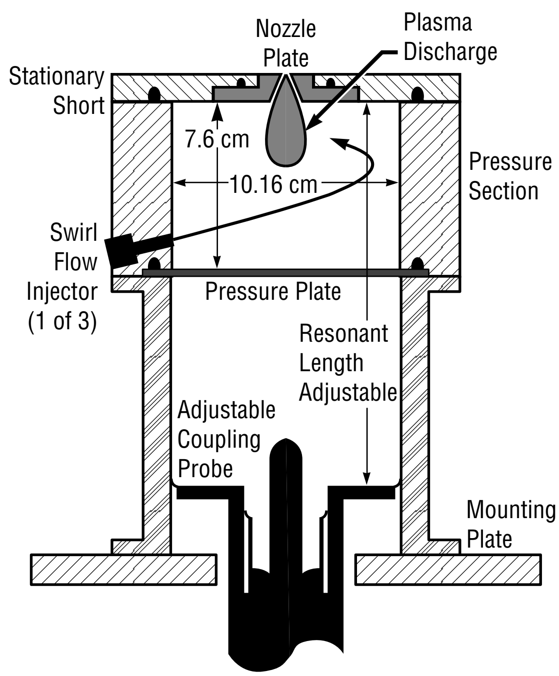
While this work gives us a base point from which to begin, it does not provide the necessary experimental data to validate existing codes used to predict the performance of MHD accelerators and generators. Looking at the big picture of where MHD augmentation can be used, we see a broad range of propellant, pressure, and temperatures in which we would like to operate. A single rocket would not be capable of exploring this broad range of parameters. A facility is needed where varied propellants can be heated and fed into an MHD accelerator/generator.

Some key experimental data to be gained by this type facility are:

- A velocity profile at the exit of the accelerator/generator;
- Conductivity as a function of seeding ratio, temperature, pressure, and other plasma properties;
- Boundary layer voltage drop/electrical loss;
- Validation of friction and heat transfer models used in existing codes; and
- The quantification of nonuniform velocity profiles, pressure distributions, temperature distribution, etc. and their effect on the plasma flow.

The UAH Propulsion Research Center has proposed a facility that should be capable of obtaining most of this data without firing a rocket. They plan to use a microwave plasma generator to heat various propellants. A seeding system is being designed to seed these propellants with potassium. A vacuum system is in place that will allow simulation of orbital conditions for upperstage applications. Spectrometers are available to determine temperature, pressure, and species concentrations in the plume. Laser diagnostic equipment is being sought to obtain velocity profiles at the exit and within the plume. Also, a strain gage thrust stand is being designed to measure the thrust from which the exit velocity can be calculated.

The thrust of this research is directed at validating the performance of H2OTSTUF, a solar thermal/MHD water rocket. The data obtained from this detailed study of water will be directly applicable to the augmentation of or power generation by a lox/LH_2 rocket, as water or steam is the primary combustion product from this rocket. Other propellants will be tested under this program in an attempt to determine the best



- Axisymmetric power coupling
- Dielectric pressure plate does not detrimentally affect electric field distribution
- Conducting nozzle plate
- Plasma discharge forms within inlet of nozzle
- Swirling propellant injection improves plasma's axial stability
- Resonant length = 15.87 cm
- Testing with H_e, N_2, NH_3, H_2

FIGURE 1.—Microwave cavity electrothermal thruster prototype design.

propellant combinations for MHD acceleration/generation. Other chemical rocket exhaust can be studied in the system by heating the products that would be obtained in their respective chemical reactions with the microwave plasma generator. Also, air could be heated and accelerated to verify necessary operational parameters in a ducted MHD rocket.

The development of this laboratory is the next logical step for the MHD program. With the experimental validation of existing MHD codes, an optimal system can be found through numerical simulation, thus allowing a prototype of this optimal system to be designed, built, and flown. The expertise to accomplish these tasks is available by combining the resources and personnel of the Marshall Center, the University of Alabama in Huntsville, and the University of Tennessee Space Institute.

Sponsor: Advanced Space Transportation Program

University Involvement: UAH Von Braun graduate fellow Jonathan Jones

Biographical Sketch: Tony Robertson, of the Component Development Division in the Propulsion Laboratory, has been serving as an advanced propulsion engineer and technical manager in several areas of advanced propulsion since 1995, including magnetohydrodynamics and magnetic levitation. Robertson provides support to Program Development and the Advanced Space Transportation Program in these and other advanced propulsion areas. Robertson earned a B.S. in physics and mathematics from the University of North Alabama in Florence, AL, 1982; earned a master's in operations research from the University of Alabama in Huntsville, AL, 1993; will soon complete a second master's in engineering management from the University of Alabama in Huntsville, AL, (mid-1997); and plans to seek a Ph.D. in engineering management.